Darek ERIKSSON :
Contibution à la Théorie de la Modélisation Systémique

Cette étude des fondements théoriques et épistémologiquse de la Modélisation Systémique, rédigée par un chercheur suédois pariculiérement actif au sein duProgramme européen MCX, Darek Eriksson, a été publiée en 1997, dans la **Revue "Cybernetics and Human Knowing". Vol. 4 no. 2-3 1997**. *Le programme européen MCX remercie chaleureusement le rédacteur en chef et infatiguable animateur de la revue , Sören Brier http://www.flec.kvl.dk/sbr/index.htm et son éditeur (publisher) Ed. of Cybernetics & Human Knowing www.imprint.co.uk/C&HK, de nous autoriser confraternellement à publier ici la version intégrale de cet article original.*

A Principal Exposition of Jean-Louis Le Moigne's Systemic Theory

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Abstract

The aim of this article is to present to the reader the theoretical construction of Jean-Louis Le Moigne. It starts with a discussion of the background that is relevant for this construction, which is: a few words about Le Moigne himself, some influences on his thinking and an overview of the theoretical framework together with some domains of application. The following exposition of Le Moigne's Systemics (LMS) is articulated in three groups: the what, the why and the how of knowing.

The *what* presents the two basic hypotheses of LMS' epistemological version, called Projective Constructivist Epistemology. These are: the phenomenological and the teleological hypotheses. The three dominating properties of the first hypothesis, that is the irreversibility, the recursivity and the dialectics of knowing, are presented as well.

The *why* question presents the criterion for validation, which is projective (or cognitive) feasibility, to be contrasted with the positivist's aspiration for objective truth. This presents LMS' solution to the dilemma between objectivity and relativism. Projective feasibility is possible due to

the so-called social contract and the autonomy of science as a domain of thought, both are discussed.

The third question, the *how*, presents a set of cognitive instruments for knowledge constitution. These may be articulated in three sub-categories: modelling rationality, systemic modelling and inforgetic theory.

Under the label of modelling rationality the following topics are discussed: formalism, procedural rationality, conjunctive or self-referential system of logic and the discussion of the method for conduct of good reason.

Secondly, systemic modelling discusses: complexity, modelling, the canonic model of a General System, LMS' modelling instrument called Systemography, the canonic model of a General Process, the canonic model of Information Processing System, LMS' instrument for articulation of complex systems called Teleological Complexification of Functional Levels, a general and a priori identification of pertinent levels of complexification of a complex system's organisation as manifested in the canonic model called Decision-Information-Organisation System, and finally the paradigm of an active organisation: Eco-Auto-Re-Organisation with its canonic model of organisation, the latter is a conflictful conjunction of three recursive functions: to produce and self-produce, to relate and self-relate, to maintain and self-maintain.

Thirdly, inforgetic theory refers to the conceptual relation between information and organisation. It includes: the canonic model of information: Signified-Sign-Signification, the first principle of inforgetics: the principle of self-organisation, and the second principle of inforgetics: the principle of intelligent action. Finally, the article gives a brief summing up of the significance of Le Moigne's contribution.

1. Introduction

For over a quarter of this century, Jean-Louis Le Moigne has developed a particular version of constructivist epistemology and a theory of systemics founded on that epistemology. His works are not well known to the Anglo-American community. This paper is an attempt to remedy this by making a general presentation of the main ideas of Le Moigne's works.[1]

The present exposition starts with a short background presentation that includes a few words about Le Moigne, a brief discussion about the intellectual influence on his thinking and a brief overview of his theories. That introduction will then be followed by the main exposition of Le Moigne's theoretical construction. Finally, we briefly sketch a summing up of this contribution's significance.

2. Some Background

2.1. A few words about J-L Le Moigne

Jean-Louis Le Moigne, born in 1931, is professor of Systems Science at Aix-Marseille University III in France. Le Moigne was educated as an engineer. For a short while he participated in the French military intervention in Algeria, which left some marks on his thinking. Le Moigne spent 13 years as a scientist, engineer and then manager in a large French industrial company. He was one of the firsts in France to apply an operations research approach to problem solving in industrial domains. That activity seems to have left some traces. Indeed he was very unhappy with the natural science and engineering approaches behind problem solving in human activity systems. He considered them to be limiting and inadequate for such tasks.

Due to the student revolt in the 1960's, the French universities started to look for managers to join them, in order to contribute with their experience and thinking. Le Moigne was one of these. For a start, he spent a year in the United States, first at the Harvard School of Economics and then at Massachusetts Institute of Technology. In his comments (Le Moigne 1989a) it is clear that he was surprised and disappointed about the superficiality that education implied. It is also clear, that this period exposed him to some ideas that came to affect his thinking and theory construction in a certain way. An example of the latter is H.A. Simon's (1969) "The science of the artificial", or Z.S. Zannetos' (1968) "Toward intelligent management information systems".

When Le Moigne started his teaching at the university, he found himself in a problematic situation. He was supposed to teach a discipline that was called by the Anglo-American world 'Management Information Systems', that is, the application of computer systems to problem solving in socio-economic contexts. This intellectual domain, then rather ill-defined, did not have enough theoretical qualities. Le Moigne considered the small theoretical contributions that existed either fragmentary or, due to his own experience, unusable. He started to look for more substantial theories and used the domain of system science as a guide in his endeavour. For more than 25 years he has constructed, reconstructed and conjuncted theories in order to support his students with cognitive instruments in their future professions. Among others, Le Moigne is the co-founder and director of the research group GRASCE[2] that has its laboratories at Aix-en-Provence. He is chairman of MCX, which is an organisation for modelling of complexity. He has published numerous of articles and books, mainly in French. (Le Moigne 1989a)

2.2. Some influences on Le Moigne's thinking

Le Moigne (1994) often states that the main impression for his works is due to what he calls the golden triangle of PSM. This is J. Piaget, H.A. Simon and E. Morin. Indeed these influences are not difficult to recognise. He also mentions sometimes the so-called three V's, that is L. da Vinci, G.B. Vico and P. Valéry (Le Moigne 1994). These are certainly not as dominating as the golden triangle but have still left some visible traces. The two triples are however not the only influences. One of the main merits of Le Moigne's work is the ability to bring together large amounts of literature from very different disciplines into a coherent unity, which few would expect possible. A sample of some names may be mentioned: G. Bachelard, G. Bateson, A. Bogdanov, K. Boulding, H. von Foerster, A. Korzybski, R. Mattessich, F. Varela, N. Wiener.
The discussion of all these influences would certainly require another article. A short comment on the golden triangle will have to suffice. Jean Piaget's works on genetic epistemology (Piaget 1970) are a clear foundation for Le Moigne's own epistemological dialect. Further, Le Moigne (1977-1994) synthesised Piaget's (1968) structuralist theory with N. Wiener's (1948) cybernetic. That exercise resulted in Le Moigne's systemic model, which is the kernel of his General Systems Theory (Le Moigne 1977-1994). Piaget's (1967) system of sciences is clearly visible in Le Moigne's (1995b) own contribution to that topic, also affected by Morin's notion of cyclical complexity. It was Piaget - shortly before he passed away - who personally encouraged Le Moigne to continue his ongoing project.

Herbert A. Simon's contribution to science in general is broad, concerned with, for example organisation theory, management science, economics, computer science, artificial intelligence and psychology. These aspects are visible in Le Moigne's approach, for example in his conception of systems science as a science of design (Simon 1969). Further, Newell and Simon's (1972) Information Processing System theory has a central role as an instrument for representation and symbol manipulation. Simon's (1976a) conception of social organisation - that to organise is to decide rather than to produce, as the Taylorian school postulated - is visible. Further, the science of decision (Newell & Simon 1972, Simon 1982) and the strong teleological emphasis is also evident. Finally, following Simon (1976b), Le Moigne has focused a procedural reasoning rather than an substantive.

Lastly, Edgar Morin's monumental project in conceiving of a new science, as expressed in La Méthode (Morin 1977, 1980, 1982, 1986, 1991; Le Moigne & Atias 1984) has had quite a general influence. Morin's conception of complexity implies the necessity for complexification rather than reduction, this in order to make phenomena intelligible. This approach seems to be fundamental for Le Moigne. Further, Morin's dialogic or recursive approach to reasoning is evident in Le Moigne's conception of the general model of organisation and also in his cyclic system of sciences (Le Moigne 1990a, 1995b).

Altogether, the conjunction of the golden triangle is probably most elegantly manifested in Le Moigne's conception of a decision epistemology (Le Moigne 1982, 1986a, 1995a). While Piaget was inspired by Husserl, Simon by Carnap and Morin by the Hegelian dialectic, Le Moigne's conjunction of the three perspectives has led to the emergence of a new argument. Hence the epistemological spectacles of the three contributors are exchanged for the newly emerged one.

Finally, while Le Moigne has synthesised and transformed hundreds of influences into a unique system of thought, he would never claim ownership of it. Rather it belongs to the systems community[3]. This theoretical construction will however, be labelled in the present text as Le Moigne's Systemic, or just LMS. This metaphor is used here mainly for practical reasons but also because of the fact that the process of construction, reconstruction and conjunction has clearly been done by Le Moigne himself.

2.3. An overview of LMS

The present section gives an overview of LMS' theories discussed in the rest of this paper (see Figure 1). When discussing a theory of knowledge[4] three main questions may be posed: *What* is knowledge? - Le Moigne calls it a gnostic question - [A]; How to appreciate the value of the knowledge, hence *why* is knowledge valid? - Le Moigne calls it an ethical question - [B]; and *How* is knowledge constituted or engendered? - Le Moigne calls it a methodological question - [C].[5] (Le Moigne 1995b)

To the question *what* is knowledge? [A], LMS provides two basic hypotheses: the phenomenological hypothesis [A1] and the teleological hypothesis [A2]. The first can be characterised by three dominating properties: knowing is irreversible [A1a], recursive [A1b] and dialectic [A1c]. The second question we shall discuss here, that is *why* is knowledge valid? [B], can be conceptualised on two levels. First, the validation of knowing is postulated as due to the criterion of projective feasibility [B1]. Secondly, the domain of science in general is postulated to be autonomous [B2]. The third and final question discusses the methodological aspects of *how* to construct knowledge [C]. The answers to this can be conceptualised in three groups: the first group, called here Modelling rationality [C1], includes procedural rationality [C1a] rather than substantive, a conjunctive system of logic [C1b] rather than the one of excluded thirds, and LMS' own method [C1c] rather than accepting Descartes'. The second group, called here Systemic Modelling (SM), [C2], and which may be contrasted with the generally accepted Analytical Modelling (AM), includes the following: a canonic model of a General System (GS), [C2a], LMS' basic modelling tool called Systemography (SGR), [C2b], a theory of a General Process (GP), [C2c]. The latter is a foundation of SM's modelling tool for articulation of relations between processors in a system; here it is called Teleological Complexification of Functional Levels (TCFL), [C2d]. LMS offers also a paradigm of organisation, expressed in the concept of Eco-Auto-Re-Organisation (EARO), [C2e]. This paradigm considers organisation to be a property of a system. That property is a conjunction of functions that is active and full of conflict, rather than just a passive structure. The third group is the Theory of Inforgetics [C3], which focuses on the relation between information and organisation, eventually mediated by a decision. Inforgetics may be contrasted to the theory of energetics, the latter focuses on the relation between matter and energy. Inforgetics offers the Principle of Self-Organisation [C3a] and the Principle of Intelligent Action [C3b]. These two may be juxtaposed with energetics' principle of mutual conservation between energy and matter (or entropy) and the principle of least action (or maximum-from-minimum).

LMS has also produced a certain number of applications, both on the meta or epistemological level and on the object or theoretical level. The first one includes: decision sciences epistemology of organisation, cognition sciences epistemology of decision, epistemology of management sciences, cognition sciences epistemology of intelligence symbolisation, epistemology of communication sciences, epistemology of informatics or sciences of computation, epistemology of technology or sciences of engineering, epistemology of design sciences, and epistemology of education sciences (Le Moigne 1994b).

Secondly, on the object level, LMS has been the foundation for Le Moigne and his colleagues in research and theoretical construction in diverse areas. Le Moigne has mainly but not exclusively developed theories for decision support and organisational information systems, and organisational theory (Le Moigne 1973, 1974a, 1974b, 1975, 1981, 1983b, 1984a, 1985b, 1986a, 1986b, 1987a, 1992; Le Moigne & Landry 1977a; Le Moigne & Carré 1977b; Le Moigne & Pascot 1979; Le Moigne & Sibley 1986; Le Moigne & van Gigch 1989, 1990e; Le Moigne & Bartoli 1997), among others. A sample of other's applications include: organisation information systems and software modelling (Bartoli 1991a; Quang and Charter-Kastler 1991; Adreit 1994; Avenier 1996; Eriksson 1996); logistics (Bartoli 1991b; 1994a; 1994b); group decision support systems (Orillard 1992); organisational and business modelling; (Bartoli 1992; Vidal 1996); and strategic management (Avenier 1992a; 1992b; 1995).

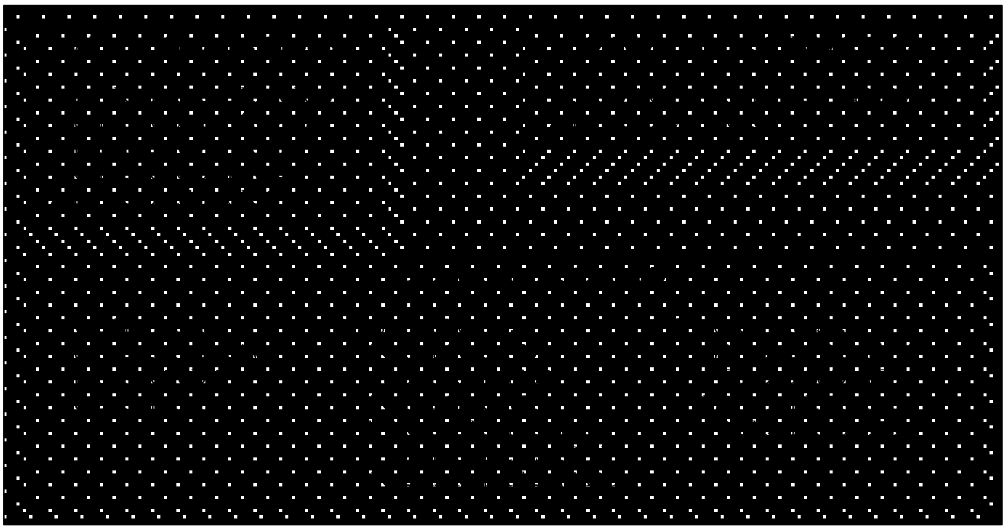

Figure 1. *Shows a principal overview of Le Moigne's Systemics. The scheme is articulated in three main domains; this is in accordance with the three basic questions that characterise epistemological discussions: the assumptions of* ***what*** *is knowledge, the criteria of* ***why*** *knowledge is valid, and the methodological instruments that support knowledge development, i.e.* ***how*** *to constitute knowledge.*

3. The Epistemological Foundation

The whole family of constructivist epistemologies as such share the anti-positivist and anti-realist position. Some members of this family are: J. Piaget's (1970) dialectic constructivism, radical constructivism due to E. von Glaserfeld (1995) and P. Watzlawick (1977, 1984), H. von Foerster's (1984) second order cybernetic constructivism, or G. Bateson's (1971) pragmatist constructivism. (Le Moigne 1993, 1995b) Le Moigne's conception is labelled Projective Constructivist Epistemology (PCE); this is due to the dominating teleological hypothesis (Le Moigne 1995b). [6]

Further, most epistemologies refer to a few basic hypotheses, often implicitly and in different terms. The following presentation is done accordingly.

3.1. The phenomenological hypothesis[7]

"An existing and knowledgeable reality may be constructed by its observers who are then its constructors (or modellers)." (Le Moigne 1995b:39). In short, the phenomenological hypothesis postulates that the knower knows a phenomenon only due to artificial representations of subject-object interactions.

The action of knowing does not start by the knowledge of self or by the knowledge of things as such, but by that of their interactions. This interaction reflects the inseparability of the act of knowing an object and the act of self-knowing, as exercised by the knower. It is this cognitive interaction between the known experience - rather than an ontic reality - and the knowing subject, which forms - at the same time - the knowledge of the phenomenon and the knowledge of the subject. Hence, the often used expression: intelligence organises the world by organising itself (Le Moigne 1994, 1995b).
The postulate that human beings know only inter-actions implies that knowing is an active construction. The known reality is then a phenomenological reality constructed by the subject due to her/his experiences in her/his neural system. When the cogniser or knower knows only interactions and not the substances then the knowledgeable reality is a reality of action. This reality is constructed by a knower through symbolic interactions: schemes, letters, numbers, phonemes, etc. (Le Moigne 1980a, 1995b).

Knowledge is built up from the beginning by the subject and there are no givens, nor objective empirical data or facts, nor innate categories or cognitive structures. The initial argument is then of absolute primacy of the knower, capable of attaching value to the knowledge that it constitutes. This knowledge then does not have sense nor value outside the particular knower. Therefore, the knower is not able to postulate the existence or not, of a knowable reality that is strange to her/him. For the cogniser the unknown is only knowledge in the instance of actualisation. Thus the metaphysical or theological question of eventual unknown reality does not make sense for the knowing subject. (Le Moigne 1995b)

Further LMS states: "The experienced knowledge by a cognitive subject, whether it be tangible or physically felt, or intangible or cognitively perceived, is knowledge if he attributes it some proper value." (Le Moigne 1995b:67). A value then, if it is the subject's own choice, can not be considered independent of the knowing subject, which would be the value of objective truth. A knower's value of her/his knowledge is practice dependent for its appreciation of consequences of actions that it elaborates when referring to this knowledge. In this case the apparent simple criterion of objective truth - or revealed - proves to be less appropriate when characterising knowledge (Le Moigne 1995b).
As a consequence of this impossibility of objective knowledge, the question of alternative criteria of validation emerges. Generally, constructivist epistemologies associate themselves with the inter-subjective property of knowledge, implying that mental schemes of different subjects may fit each other. According to Le Moigne (1995b) however, this is the same as the American pragmatist's thinking of knowledge validation. This

postulates the feasibility criterion and expresses value in all knowledge. Le Moigne (1995b:68) gives the following illustration: ”It is difficult to evaluate the objective truth of our knowledge relative to human rights but one may reasonably consider that this knowledge was less easily ‘teachable’ in the slavery ancient Greece than, for example, during the American Secessionist War.” (The argument of validation will be discussed further in the section 3.3.)

Finally, the value attached to knowledge must be accessible somehow. This is exercised through the artificial mediation of representations constructed by the subject itself with the aid of a system of symbols, or to use Le Moigne’s (1995b:69) expression: ”/.../ representation constructs knowledge which represents it.” Then the problem posed to all paradigms, from realism to idealism, by the significance of the correspondence between knowledge and representation is given the phenomenological answer by PCE. Le Moigne (1995b:69) uses Korzybski (1931-1980) to illustrate this argument in the following manner: ”The map - or representation - is not the territory or a knowable reality independent of the subject /.../”, rather ”/.../ the map expresses experimental knowledge of the territory by the subject, which sometimes transforms it /.../”, therefore: ”/.../ if the map is not the knowable territory, the known territory becomes the map.”. Le Moigne (1995b:44) summarises this as follows: ”We do not know reality except through names or representations we attribute to individuals through whom we perceive it. It might not be a ‘true’ reality which we know but an artificial representation (names) that we associate with it.”. This inseparability of knowledge and its representations as understood in their inter-activity of intentional experience of the knowing subject and the subject’s constructions that represent this phenomenological knowledge, is a basic hypothesis of LMS.

The following three sections will discuss the three dominating characteristics of the phenomenological hypothesis: the irreversibility, the recursiveness and the dialectics of knowing.

3.1.1. Time and irreversibility of knowing

The irreversibility property postulates that knowledge is an action rather than a result, knowing rather than knowledge. Such a notion refers to the Heraclitan formula, stating that one cannot enter the same river twice... This quality concerns the status of time relating to action; more precisely the irreversibility of action. It may be contrasted with its antithesis due to classic Newtonian mechanics, which presumed total reversibility of phenomena and time.

”The absolute instantaneousness seems inconceivable to the knowing subject, because he never had such a cognitive experience.” (Le Moigne 1995b:73). The concept of action implies that the temporality that is perceived is irreversible. LMS uses the works of Bergson, Costa de Beauregard and more recently Prigogine with Stengers (1979), but also referring to R. Dubos (1981). The latter wrote a little before he passed away: ”/.../ the time will come when one will realise that the theory of rigidity of interior environment of C. Bernard is no longer so valuable /.../ the scientists will realise that all changes are irreversible /.../.” (in: Le Moigne 1987a:12).

3.1.2. Auto-reference, recursiveness and inseparability of knowing

This characteristic of knowing allows the knower to accept the cognitive act of self-reference, forbidden since the Aristotelian logic of excluded thirds. LMS reconsiders the notion when a proposition includes itself as a referent, due to the works on living systems of Varela (1975, 1977) who builds on Spencer Brown's laws of form. Further, von Foerster's (1959) and Bogdanov's (1980) works have clearly left their traces as well; the latter focuses on the cognitive function of joining. (Le Moigne 1980a, 1985a)

The recursiveness of cognition recognises the inter-dependence between the subject and the object. This accounts for a case when an operand, in the same system and at the same time, may also be an operator. LMS stresses that everyday experience conforms that the human mind is capable of conjunctive reasoning as well as of disjunctive reasoning. This expresses itself in grammar (verbal substantive) and rhetoric in an intelligent way; for example, the concept of organisation expresses, at the same time, the action and the result: an organisation organises itself thus becomes (re-) organised. (Le Moigne 1990a)

3.1.3. The dialectics of knowing

The dialectic property was well focused in the discussion of the phenomenological hypothesis above. It concerns the interactionist paradigm: "/.../ the emerging system is both more and less than the sum of its elementary parts /.../" (Le Moigne et al. 1992:10). Dialectics may be contrasted with and is a conjunction of two alternative paradigms, the individualist or atomist and the holist paradigms. The atomist considers the superiority of the individuals of a particular system over the whole systems they are a part of. On the other hand, the holist paradigm: "/.../ considers that the fundamental explanation of a phenomenon is to be found due to the action of the superstructure over the parts of the system /.../" (Le Moigne et al. 1992:10). Hence, while the individualist approach focuses on the diachronic property and the holist on the synchronic, the interactionist stance manifests both. This was elegantly expressed already by Pascal (1963:Thoughts no.72) "/.../ I hold it equally impossible to know the parts without knowing the whole and to know the whole without knowing the parts."

3.2. The teleological hypothesis

The seminal article of N. Wiener, A. Rosenblueth and J. Bigelow (1943) "Behaviour, Purpose and Teleology" acted as a kind of catalyst for the epistemological mediations, reintroducing the old thesis of teleology. The everyday experience shows that the same cause do not always lead to the same effect, as was proclaimed by Boudon (1968). The latter showed that there are four possible correspondences and not one, between the occurrences of two sets of events: A and B. Occurrences of B may in effect be rationally identifiable and interpretable according to whether the occurrence of A is or is not necessary to it, and whether it is or is not sufficient to it. In one correspondence A is a causal one, hence a necessary and sufficient condition to B. While in the three others it is not the case[8] - 'an acorn does not always cause an oak'. Thus Le Moigne (1977-1994:38) asks whether they are: "/.../ devoid of reason and not worthy of rational knowledge?"

Attributing to the knowing subject the decisive role in the construction of knowledge, the phenomenological hypothesis takes into account the intentionality, or finality (or aim, end, goal, objective, purpose, projectivity, aspirations...) of this knowing subject's mind. This meaning of the interpreted phenomenon is then assigned in reference to one or more ends which in itself do not necessarily impose or imply any ontological validity. Denying the free will of the knower, the big-brother hypothesis of determinism seems less plausible to most cultures today. The shadow is still visible of Kepler, Galileo and Newton's imposed conviction that the world is endowed of a structure and order, incorporating cause-and-effect laws. (Le Moigne 1994)

In summary, the two basic hypothesis of PCE, postulates that the knower knows only intentional representations of dialectic inter-actions between experiences of the subject and the subject itself. These are recursive and irreversible, and constructed and organised actively by the knower. Hence PCE's conception is different from Piaget's dialectic constructivism, which considers itself to be an idealist-realist oscillation, even though it expressed the goal-oriented property, seemingly in a teleonomic rather than in a teleological way. Table 1 illustrates the what-question of PCE.

PARADIGM:	CONSTRUCTIVIST	POSITIVIST & REALIST
1st Gnostic hypothesis:	Phenomenological	Ontological
characteristic 1:	Temporal irreversibility	Total reversibility
characteristic 2:	Included thirds	Excluded thirds
characteristic 3:	Dialectic	Individualist
2nd Gnostic hypothesis:	Teleology	Determinism

Table 1. *Shows a juxtaposition of the basic hypothesis of* ***what*** *is knowledge. The juxtaposed positions are the constructivist paradigm and the positivist and realist paradigms. The two basic hypotheses of constructivist position and their properties, may be also expressed in three cognitive properties, which are:* ***synchronicity****,* ***diachronicity*** *and* ***autonomy****. These are well visible in the methodological arsenal of Le Moigne's Systemics.*

3.3. The validity of knowing

The issue of knowledge validation will be discussed on two conceptual levels; first the validation of a particular statement and secondly the validation in terms of the whole epistemic theory considered as a scientific domain. These two are necessarily inter-related and support each other. The first theme has already been discussed briefly in the discussion about the phenomenological hypothesis. This kind of repetition manifests the recursivity of this theory.

3.3.1. From objective truth and the metaphysical contract - To projective feasibility and the social contract

As discussed previously, constructivist epistemologies in general postulate the inter-subjective criterion for validation. It means that the mental schemes of different knowers are to fit each other rather than match perfectly each other or an ontic reality (see for example von Glaserfeld 1995). PCE however, postulates that behind this reasoning the criterion of feasibility is to be recognised. In this regard, LMS refers to the American pragmatist philosophy, for example J. Dewey's pragmatism (or instrumentalism) but also to Vico's (1710): 'truth lies in the doing'. Given this, PCE postulates the criterion of Projective Feasibility. It implies that truth is what the experiences of a knower, or group of knowers, manifest as feasible due to their intentional actions. This criterion is founded on the hypothesis of intentional and active construction of knowing, preferably carried out with procedural reasoning (the latter to be discussed in the following). That notion may be contrasted with the criterion of objective truth, founded on the hypothesis of passive reception of a given object, which is carried out with substantive reasoning. (Le Moigne 1993, 1995b)

The PCE may be asked for self-validation, especially while one of its main properties is the self-referential quality. Le Moigne (1995b:40) delivers the following reasoning. "The power of the hypothesis of constructiveness of the knowable reality stems from its plausibility and its effectiveness. Its weakness, in the cultural context of the era, stems perhaps from its de-sanctifying effect on scientific knowledge." Hence, rather recursively, LMS postulate that it is plausible or feasible to use the criterion of projective feasibility. More specifically, for LMS to propose an epistemological foundation and therefore criterion for knowledge construction implies a social contract for the socio-cultural system that is supposed to develop this knowledge. This knowledge ought to then hold some identifiable value for this culture as expressed in sense, intelligibility or effectiveness (Le Moigne 1995b). The criterion of projective feasibility applies to the whole epistemological foundation. On the other hand Le Moigne (1995b) notes that, if this truth is an illusion, then the socio-cultural system does not accept any more the criteria of knowing. This seems to be the case with positivist's conception of objective knowledge, in this case such an epistemological system and its ethical value has no longer any basis. This is because: "No scientific or cultural authority could have the monopoly of determination of ethical value of knowledge. But epistemology is best placed of all disciplines to recognise and show questions on the value of knowledge, by which in some way, it ensures the scientific status." (Le Moigne 1995b:88). This social contract of epistemological foundations is possible to exercise due to LMS' notion of an autonomous science, hence the epistemology may be 'best placed' to examine its own foundations. The argument of scientific autonomy is discussed next.

3.3.2. From the science of autonomy to the autonomy of science

In the discussion above, LMS argues for the validity of an epistemological system in reference to the social contract. Epistemology is postulated to be '...best placed of all...' to ensure its own foundations.

The initial question is: "Can science be understood enough to self-produce its own foundations?" (Le Moigne 1983a, 1994:25). According to LMS, tackling this issue exposes a paradox: while science in general can today speak of a particular science of autonomy[9], it still does not recognise the autonomy of the science in general. LMS blames the positivist shadow for this situation. In order to manage this paradox LMS twists the premise affirming the existence of the science of autonomy, and it presents some criteria to recognise the domain of thought that may be called science. LMS uses the following definition of autonomy: "Property of a system in general taking into account its aptitude to be identified and to identify itself, at the same time, different and maintained different from its substrate environments, on which it is interdependent." (Le Moigne 1983a, 1994:29). This definition is postulated to be recognised by physical, living and social sciences. According to LMS, this notion of autonomy will make it possible to ensure an autonomy of science.

Armed with this conception, LMS goes on to examine the positivist notion of science. The latter may be defined (Le Moigne 1983a, 1994:30) as: "A set of types of knowledge of studies, of universal value, characterised by a goal and a predetermined method, and based on true, objective relations." Hence in positive terms, science may perhaps be identified as different from its substrate (a subset of knowledge-types capable of differentiation of culture...). But it could not identify itself as such (as an object of knowledge, it precludes itself from being the subject of knowledge) and above all, it precludes itself from maintaining its specific difference from the substrate environment (the culture) because it wanted to assimilate, by successive annexations, its substrate. Hence since Comte, science forbids itself to be autonomous because of the postulation of previous determinants, that is something can not be autonomous if it can not differentiate or identify itself. (Le Moigne 1983a, 1994)

LMS notes that the positivist tradition has attempted to escape from this conception. Examples of this kind of succession from inside positive epistemology are Popper's (1959) "Logic of Scientific Discovery", which postulates that a proposition may be scientific and false. Another attempt was due to T. Kuhn's theory of paradigms suggesting the relativity of epistemology.

LMS on the other hand approaches the problem from another avenue. It associates itself with Piaget's (1967) classification of science, arguing that it is still one of the most adequate. Piaget's system suggests the forgotten paradigm of the science of ingenium, more recently known as the science of design, the science of artificial (Simon 1969), and for LMS the science of systems. The science of design is considered as complementing or as an alternative to the natural or analytical sciences. Armed with this notion, LMS draws the following conclusion: "Science thus understood does not uphold the ideal of an asymptotic approach of some immanent truths (progress), it wants to be the edification by humanity (design-construction) of its own natural state; nature for science ceases to be a gift (natural) in order to become a work (artificial)." (Le Moigne 1983a, 1994:38)

The paradigm of design and therefore of organisation offers a liberating interpretation of science: "/.../ organisation of appearances by a system of principles /.../" instead of "/.../ revelation of laws /.../" (Le Moigne 1983a, 1994:39). Organisation of appearances is then a characterisation of non-positive epistemology where organisation - the fundamental paradigm - is a nucleus of all theories. The organisation of appearances focuses on the organisation of perceptions; perceptions that are both sensations and judgements because to feel is to judge. "To inform one self or to feel, is to decide to inform one self and therefore to judge." (Le Moigne 1983a, 1994:39) LMS considers science as an organisation of perceptions and conceptions and therefore of knowledge.

LMS draws attention to J. Ladriere's (1975) definition of science that appreciates its recursive and non-linear character: "One could say that science is a critical mode of knowledge. The qualifier 'critical' indicates on the one hand that science exercises vigilant control over its own advances, on the other hand that it works out methods that permit it to extend in a systemic fashion its own field of knowledge. Scientific advances are at the same time reflexive and prospective... The organising principles of science are not furnished to it by external instances; the work-out of validity criteria and methods of research intrinsically forms part of development of scientific knowledge." (In: Le Moigne 1983a, 1994)

Finally, Le Moigne (1983a, 1994:40) modifies this conception in the following manner, science is: "/.../ a mode of critical knowledge at the same time reflexive and prospective which ensures our resolution: that of scientific reality of non-positive science. This suggests our thesis of autonomy of science, such an understanding of science supports willingly the legitimacy of the science of autonomy." Table 2 shows a recapitulation of the validation discussion.

PARADIGM:	REALIST & POSITIVIST	PROJECTIVE CONSTRUCTIVIST
Search for:	Objective truth	Projective feasibility
Individual validity:	Imposition of some 'external' criteria	Subject's believe (Subject's coherence)
Collective or social validity due to:	Contract with Metaphysics or Religion	Social contract (inter-subjective coherence/fit)
Status of the scientific domain:	Not autonomous	Autonomous

Table 2. *Shows a juxtaposition of validation criteria (**the why-question**) for the two respective positions, that is, the constructivist paradigm and the realist and positivist paradigms.*

4. LMS In Action

The following sections will discuss the how-question of LMS theories. This issue is determined fundamentally and necessarily by the two questions discussed previously. Le Moigne has succeeded in formulating a significant number of theories for modelling of complex systems. For reasons of clarity, the how of LMS framework is articulated here in three categories: modelling rationality, systemic modelling and inforgetic theory. These categories are not exclusive but rather strongly interrelated.

4.1. Modelling rationality

The domain of modelling rationality includes discussions on formalism and procedural rationality, conjunctive logic and discussion of the method.

4.1.1. Formalism and procedural rationality

LMS defines formalisation as: ”/.../ the cognitive exercise allowing an action (a concrete system) to be transformed into a form (an abstract system) /.../)” (Le Moigne 1993:4), while the reverse operation is considered interpretation. These concrete and abstract systems are considered as systems of signs, eventually systems of symbols. Consequently, formalism is defined as: ”/.../ a symbolic system of rules carrying out such a process of transformation of experiences into knowledge /.../. Formalism is therefore any system of signs resulting from formalisation.” (Le Moigne 1993:4) This notion of formalism does not reduce formalism to the traditional logical and mathematical formalism. LMS owes this approach to Simon (1976b:304) who wrote: ”/.../ formal models which, however rigorous, do not resemble very close the models using traditional mathematics.” (Simon exemplifies the argument with the science of chemistry). Le Moigne (1993:5) pursues with: ”The moralist, the jurist, the grammarian, the rhetor and, sometimes, the poet, all know this form of ancestral experience.” Hence: ”/.../ rigour is understood as the reasoning process developed to an explicit system of axioms, /.../ which are not necessarily those of deduction and non-contradiction.” From this point of view, the three axioms of Aristotelian logic - which shadow the occidental science (and are presented in the following section on conjunctive logic) - are only one possible system of formal axioms among others, not more or less rigorous. Le Moigne (1993) notes that even Aristotle did not consider them to be imperative to reason.

In contrast to the postulated neutrality of deductive logic, Simon (1973, 1976, 1977) took into account the infinite capacity of the multiple procedures that the reason can construct, followed by eventual action. Le Moigne (1990a) observes that Simon (1969) has shown in a convincing fashion, that from an action a state can be deduced but not the reverse. Thus, LMS priors procedural rationality that focuses deliberative, argumentative or dialectic heuristics. In contrast, substantive rationality focuses on deductive, syllogistic or algorithmic reasoning (Le Moigne 1977-1994, 1990a, 1993, 1995b, 1995c; Le Moigne & Bartoli 1994). The procedural course allows mastering forms of reasoning that were banned by deductive logic; such are: reflexiveness, recursiveness, self-referentiality, irreversibility, trial and error experimentation, analogue and dialectic reasoning through heuristic searches (Newell & Simon 1976). This approach aims reasoning, first of all, to produce meaning rather than running it by giving all emphasis to form. For example the system of musical notations is ineffable, inexpressible and non modelable in the strict analytical or substantive sense. LMS accepts the modesty of procedural reasoning that implies an: ”/.../ absence of any universal criterion of ultimate validation other than ‘beliefs’ of the actor.” (Le Moigne 1993:10) Consequently, LMS adopts Simon’s (1983) meta-heuristic: ‘searching is the end’, operationalised in heuristics of trial-and-error experiments due to teleological models of successive and endless transformations of representations. (Le Moigne 1993) This meta-heuristic implies that the goal of human beings is to search for their goals and means of being. Table 3 summarises this discussion.

PARADIGM:	POSITIVIST & REALISM	PROJECTIVE CONSTRUCTIVIST
Preferred mode of rationality:	Substantive reasoning	Procedural reasoning
characteristic 1	Syllogistic reasoning	Rhetoric, Dialectic-Hybrid reasoning
characteristic 2	Deduction	Induction, Abduction, Transduction, Retroduction[10]
characteristic 3	Algorithmic reasoning	Heuristic reasoning
characteristic 4	Formal logic (OR-logic)	Natural contemporary logic (AND-logic)

Table 3. *Shows a juxtaposition of the reasoning rationality modes and some of its characteristics, for the positivist and realist paradigms and the constructivist paradigm, respectively. Characteristic four, that concerns the respective paradigm's system of logic, is presented more extensively in Table 4 below.*

4.1.2. Conjunctive logic

As suggested in the discussion on procedural reasoning, epistemological mediation of LMS implies a reconsideration of the Aristotelian axiomatics, that is the foundation of the formal disjunctive (OR) logic of excluded thirds. This logic of excluded thirds has been culturally established by followers such as: Boolean logic, Frege, Russell and Whitehead. According to Le Moigne (1977-1994) reconsideration is crucial because: "The only constraint that the theory imposes on the modeller is the one of a prior verification: Had he shown some axioms with which he will progressively support his inference and engrave his design? But he should freely choose these axiomatics, and no theory will calculate it for him.". Before exposing LMS' system of logic, a brief recounting of the Aristotelian or disjunctive logic is given to make the argument more intelligible. First is the axiom of identity: that which is, is: 'A is A'. Second, the axiom of non-contradiction: nothing may be and not be, at the same time, hence: B may not be at the same time A and not-A. Third, the axiom of excluded thirds: everything should either be or not be: B is either A or not-A. This system of logic exclusively supports deductive reasoning. A problem arises when a proposition includes itself as a referent. This issue has been a problem since Aristotle, yet it has been ignored. Consequently, if A designates Truth, the sign not-A should necessarily designate the opposite to Truth, that is: False; and no other significance could be associated with the signs A and not-A. This disjunctive logic (OR-logic) does not account for everyday phenomena that humans experience in their complexity, as conjunctive. These are natural because they are represented in everyday language by a number of concepts often through verbal substantives. For example the concept of organisation may be both a process and a state at the same time. (Le Moigne 1990a)

LMS associates itself with works such as Korzybski's (1931) proposition to formulate a non-Aristotelian system of logic with the purpose of allowing expressions of reasoning unconstrained by the axiom of excluded thirds. But also with Varela's (1977) work on autopoiesis, which requires a self-referential epistemology and with Piaget's proposed design of logic of significations (Piaget & Garcia 1987).

The generation of alternative systems is validated accordingly to the previously exposed discussion, that is: "There is not any immanent authority that shows logicians and methodologists which are the good or true axioms. The formation of a body of axioms of reference, is no doubt, a historic and cultural process. One ascertains that these marks, which we will call axioms, were already used in the past by some good minds who left us trails of their reflections." (Le Moigne 1990a:34)

LMS' alternative, a conjunctive system of logic (also called: AND-logic or self-referential logic) reflects the founding gnostic hypotheses and its properties, as presented previously. The axioms of AND-logic are as follows. First is the axiom of teleological operationality (or synchronicity). It implies that a phenomenon is meaningful, if perceived as an intentional action and not an erratic one. Second, the axiom of teleological irreversibility (or diachronicity): a phenomenon that is capable of being modelled, hence meaningful, is perceived as a transformation, forming a project in time, and having a history. Third is the axiom of inseparability (or recursivity, or included thirds, or autonomy). It axiomises that a phenomenon that is capable of being modelled is perceived as inseparable knowledge of an operation and its product; thus a product and a producer at the same time. (This is because the human experience of an object and of itself is not separable, as the Cartesian shadow imposed. For example organisation is considered both and at the same time to be a state that is organised by human cognition and a process of organisation by the same cognition). Table 4 summarises the discussion of LMS' system of logic. (Le Moigne 1977-1994)

PARADIGM:		POSITIVISM & REALISM	CONSTRUCTIVISM
System of Logic:		Analytic logic	Systemic logic
	1^{st} axiom of:	identity	teleological operationality
	2^{nd} axiom of:	non-contradiction	teleological irreversibility
	3^{rd} axiom of:	excluded thirds	inseparability

Table 4. *Shows a juxtaposition of two systems of logic. That is, analytic logic (or disjunctive logic, OR-logic, logic of excluded thirds) and systemic logic (or conjunctive logic, AND-logic, logic of included thirds). They belong to the two juxtaposed paradigmatic positions, that is, the positivist and realist paradigms and the constructivist paradigm. The reader may observe the relation between axioms of systemic logic and the three properties of cognition. That is to say, axiom one and* ***synchronity****, axiom two and* ***diachronity****, and axiom three and* ***autonomy****.*

4.1.3. Discussion of the method

The traditional analytical approach to modelling seems to build its reasoning on Descartes' precepts - often implicitly. LMS' alternative to analytical modelling is systemic modelling. The latter is founded on its own precepts and which will be reviewed in this section. In order to make LMS' argument more intelligible, Descartes' four precepts will be briefly recalled. Descartes first precept is: "/.../ never to accept anything as true unless I evidently know it to be such, that is to say, carefully avoid precipitation and prevention and not to understand anything more in my judgement, than that which presented itself so clearly and so distinctly to my mind, that I would not have any occasion to doubt it." The second precept is: "/.../ to divide each of the difficulties that I will examine, into as many parcels as they could be and as could be required to better solve them." The third precept is: "/.../ to lead my thoughts in order, starting with objects that are simplest and easiest to know, to advance little by little, as if by degrees, to knowing of the more compound ones and even assuming order between the ones that did not naturally follow each other." Finally, the fourth precept is: "/.../ to make everywhere such total enumeration and such general reviews that I could be ensured of omitting nothing." (In: Le Moigne 1977-1994:30)

It seems that if these precepts would be applied to themselves, a doubt may emerge. On the precept of evidence, a question may be posed: are there many proclaimed proofs that are doubtless? The first precept of LMS is then of pertinence: "Agree that all objects that we consider define themselves in relation to implicit or explicit intentions of the modeller and to never forbid ourselves from doubting this definition, if in modifying our intentions the perception we have of these objects also changes." (Le Moigne 1977-1994:43). For example: "The equal sign does not have the same significance for the mathematician writing 2 + 2 = 4 and for the programmer writing N = N + 1 but for each of them this sign is pertinent in relation to their project of the moment." (Le Moigne 1977-1994:33). Thus a question of importance would be: 'What do we intend?' Secondly, concerning Descartes' reductionist precept, many thinkers since the Aristotelian precept, 'the whole is more than the sum of its parts' have expressed a similar concern. For example, taking apart a car in Great Britain is not sufficient to gain understanding why its steering wheel is on the right side, because the reason for this lies outside this system; hence the examination requires a systemic or conjunctive approach. Descartes' hypothesis of a closed system is replaced with the one of an open system: "To perceive the object already as an inserted, immersed, active part in a greater whole /.../ and to make the intelligence of this environment, the condition of our knowledge of the object." (Le Moigne 1994a:34). Interactionist precept is the second of LMS: "Always consider the object to be known by our intelligence as an integral and active part of a greater whole. Perceive it first globally, in functional relation with its environment without worrying about establishing a faithful image of its internal structure, where existence and uniqueness are never considered given." (Le Moigne 1977-1994:43). Thirdly, on Descartes' causalist precept, the previous discussion about the teleological hypothesis accounts very well for Descartes' inadequacy. Moreover LMS states: "We will not cease being rational because we will consider other hypotheses on the ends, no longer wired in the structure but perhaps programmed and multiple in some memories even programmable and inventable in recourse to some form of imagination. For the explanation cause-and-effect, intelligence substitutes through a fertile generalisation, the interpretation (or understanding) behaviour-end." (Le Moigne 1977-1994:39). Hence, the teleological precept of LMS states: "/.../ interpret the object through its behaviour not through itself, without first searching to explain its behaviour through some law implied in an eventual structure. Understand on the other hand its behaviour and the recourses it commands in relation to projects that the modeller freely attributes to the object. Consider the identification of these hypothetical projects a rational act of intelligence and agree that their demonstration will be rarely possible." (Le Moigne 1977-1994:43). In this manner, LMS propagates that teleology expresses itself through signs (and their manipulations) to be compared with Descartes' notion where causes are expressed through laws. Consequently, the question should not be of the intrinsic laws of a structure's behaviour, rather asking for explicit intentions that the behaviour should be referred to (Le Moigne 1977-1994).[11] Discussing the fourth and final precept of Descartes that is about an exhaustive search, a question emerges: Is it possible or practical to do such an exhaustive enumeration? This for example, when the concern is a socio-economic model manifesting thousands of relations between variables? Instead, LMS asks the modeller to omit a lot deliberately - with some risk of failure - and proposes aggregates - more modestly but also openly. This selects what is interesting in relation to the modeller's goals. LMS' precept of aggregativity states then: "Agree that all representation is partisan, not through the forgetfulness of the modeller, but deliberately. In consequence, research recipes capable of guiding the selection of aggregates considered pertinent and exclude the illusionary objectivity of an exhaustive enumeration of elements to consider." (Le Moigne 1977-1994:43). Table 5 summarises the method under discussion.

Finally, LMS exercises the validity of its method in the same pragmatic fashion as defined previously: "The axiom body is neither true, nor false. It only matters to us that it is not totalitarian.

One wanted only to underline the fact that it is possible to propose competing axioms." (Le Moigne 1977-1994:44).

The discussion of the method:		Descartes' analytical method	LMS systemic method
	1st precept of:	evidence	pertinence
	2nd precept of:	reduction	interaction
	3rd precept of:	causality	teleology
	4th precept of:	exhaustivity	aggregation

Table 5. *Shows a juxtaposition of two methods for conduction of good reason. That is, Descartes' method that represents the analytical approach of the positivist and realist paradigms, and Le Moigne's method that represents the systemic approach of the constructivist paradigms.*

4.2. Systemic Modelling and its instruments

Systemic Modelling (SM) is used here as a label for a set of cognitive modelling instruments that LMS offers the modeller. While SM's domain of inquiry is a complex system, it may be juxtaposed with Analytical Modelling (AM), whose domain of inquiry is a complicated system (Le Moigne 1990a, 1977-1994).

The exposition will start with a discussion of some central concepts, namely: complexity, modelling and system. This will be followed by a presentation of some modelling instruments, such as: General System (GS), Systemography (SGR), General Process (GP), Information Processing System (IPS), Teleological Complexification of Functional Levels (TCFL), the Decision-Information-Operation System model (DIOS) and the Eco-Auto-Re-organisation paradigm (EARO).

4.2.1 Complexity and modelling

"The notion of complexity implies a possible and plausible yet unpredictable emergence of a new sense inside a phenomenon, that one considers as complex." (Le Moigne 1990a:3). LMS' notion of a complex system implies per definition that it is irreducible to a single finished model. This system may be complicated or not, sophisticated or not, composed of many components and interactions or not, but it is complex. Then complexity is the attributed quality that is deliberately considered by a subject's mind in its perception or conception of something that exercises unpredictable emergent behaviour.[12] "And no tribunal is empowered to confer patents of ontological complexity." (Le Moigne 1990a:4). SM's approach admits its modesty in being satisfied with making phenomena intelligible but it does not necessarily explain them. Le Moigne (1990a) points out, by examining the etymological roots of "complex" which originates in plexus, that complex is not opposite to simple but rather to implex. This notion of complexity may be considered in contrast to analytical modelling's approach which, due to its epistemological foundations, is potent to deal with complicated systems (i.e. systems that can be explained), not with complex systems.

The next issue is modelling. It is considered as: "An action: of elaboration and intentional construction through symbols of models, of making intelligible a phenomenon perceived as complex and to amplify the reasoning of an actor deliberately intervening inside the phenomenon aiming to predict consequences of his project of possible actions." (Le Moigne 1990a:5). In other words, modelling implies intentional representation by symbols, it implies conception and design. The subject knows its objects through such a designation of symbols to these objects. Further, these symbolic constructions may be reasoned and manipulated in order to infer deliberate meaning, which may be followed by a conception of new possible behaviour. Systemic modelling is necessarily projective or teleological modelling (TM), perfectly reflecting the two gnostic hypotheses and their properties. Further, TM implies that a model of a system is necessarily recursive because it is established in an interaction between the modeller and the modelled phenomenon conceived as complex. TM implies that a model is a conjunction of the symbols or representation, of the modeller and its intention and of the modelled experience that is under consideration. (Le Moigne 1984d, 1990a, 1990c). The model cannot be separated from the modeller's action, as is postulated by AM - in its attempt to reach neutrality. This implies the shift from AM's objectivity to SM's projectivity. The constructed model is always characterised by a modeller's capacity to clarify modelling finality or finalities, in other words of self-finalisation. Consequently, the prime question for SM is: What is the problem? rather than: How to solve the problem? – as is the case with AM. SM refocuses the attention from AM's frequent monocriterion approach to multi-criteria management.[13] SM's projectivity exposes AM's dilemma, that is the unconditional obedience of natural laws, i.e. cause-and-effect relation, which reduces finality or intention to determinism. Determinism makes AM impotent when, for example, the laws are not known or the problems do not state themselves clearly - both situations are common in the domain of complex systems. While AM simplifies, reduces and analyses its phenomenon of concern, SM deliberately conceives and complexifies its consideration. Simplification of a complex phenomenon destroys its intelligibility. (Le Moigne 1990a & 1977-1994) Table 6 presents a mnemonic palette of some concepts associated with AM and SM, respectively.

MODELLING MODE:	ANALYTIC MODELLING	SYSTEMIC MODELLING
Domain of concern:	Complicated Systems	Complex Systems
Characteristics of the studied phenomenon:	Object (State)	Project (Process)
	Element (Substantive)	Active entity (Verb)
	Control	Intelligence (Knowledge)
Notion of system:	S = (Things, Relations), (a Set)	General System, (to be, to do, to become)
Notion of organisation:	Structure of passive states	Conflictful conjunction of three recursive actions. The actions are: to produce and self-produce, to relate and self-relate, to maintain and self-maintain
Mode of study:	Analysis	Design (Conception)
	Simplification	Complexification
	Causal explanation, (cause-effect study; determinative natural laws)	Teleological comprehension, (means-end study; finalisation of phenomenon)
Notion of model:	Disjuncted simplification of reality	Conception or perception of phenomenon; a conjunction of a representation (model), the modeller and the modelled
Primary questions of study:	What are the determinants? What is it made of?	What is the goal? What does it do?
	Efficacy (How-to-do?)	Effectivity (What-to-do?)

Validation:	Evidence (objective truth)	Pertinence (projective/cognitive feasibility)

Table 6. *Shows a juxtaposition of some general modelling concepts. The two modelling palettes belongs to analytical modelling of positivist and realist paradigms, and to systemic modelling of constructivist paradigm, respectively. The reader may observe the relation between the concepts of systemic modelling and the three states of cognition. This is clearly manifested in the notion of General System, that will be discussed bellow. Hence,* ***to be*** *or* ***autonomous, to do*** *or* ***synchronic and to become*** *or* ***diachronic.***

4.2.2 The genesis of modelling paradigms and the General System

At the heart of LMS is the theory of General System. The history of science has generated five main canonical models for guiding the modelling process. The following discussion will briefly review this evolution, ending with the canonic model of a General System, which is the kernel of General Systems Theory. (Le Moigne 1976a, 1976b, 1977c, 1977-1994, 1990a, 1995b)

The first modelling paradigm is rational mechanics. It was finally established at the end of 19th century and perfectly reflected the Cartesian imposition. All objects were supposed to be explained by focusing on the structure that in turn was believed to determine the function. This notion was founded on the assumption of full reversibility, where cause-and-effect was supposed to be explained by mechanics. Lord Kelvin may very well be considered one of its main ambassadors.

The second paradigm is statistical mechanics or thermodynamics, due to L. Boltzmann. It established itself as a reaction to rational mechanics. It postulated the inadequacy of 'studying the moon with a microscope'. Statistical mechanics refocused the attention from structure-function to structure-evolution, or from kinematics to kinetics. Evolution or dynamics took into account the irreversible transformations of internal structure over time, yet of a closed system.

The tension of the two modelling paradigms was elegantly dealt with by W. Weaver's (1948) problems of: simplicity (rational mechanics), disorganised complexity (statistical mechanics) and unmanageable organised complexity.[14] This tension allowed the modeller to leave the Cartesian shadow. In search for a unified avenue two new modelling paradigms emerged: the structuralist[15] paradigm that is more European and the cybernetic paradigm that is more North American.

Hence, the third modelling paradigm is the structuralist approach. J. Piaget (1968) may be seen as one of its main ambassadors. He considered it to be a method that describes an object in its totality, that is to say, one that is at the same time both functioning and evolving; hence simultaneously synchronic and diachronic or structured and structuring. This mortal blow to reductionism of the two previous modelling approaches recognised that the character of totality belonging to structures comes of itself. A structure is formed due to the elements but these are, at the same time, subordinate to the structure. For example, a human being (here an element) is affected by the culture of a society (here a structure) that she/he is part of; the structure is however affected (constructed, maintained…) by the individual, at the same time. This approach clearly exposed the limitations of causalism employed in mechanics. It limited itself however by presupposing an automatic structure, then it led itself to a dead end by modelling closed systems, as discussed above in the two previous mechanical approaches of modelling.

The fourth modelling paradigm is the second attempt to overcome the problem of mechanical modelling. Cybernetic modelling offers an inverted modelling approach of the structuralist notion. Instead of centring the modeller's attention on mechanism's or organism's structures, it proposed closing them in a black box, favouring interpretation of the behaviour, that is, a conjunction of function and evolution. The behaviour of a black box is to be interpreted in reference to its goal(s) and environment. The classic cybernetic approach of Wiener et al. (1943) and McCulloch et al. (1943) became very powerful after the introduction of the concept of informational feedback. Cybernetics did not attempt to explain the mechanisms in a system. It rather attempted to understand or interpret a system's behaviour in permanent reference to its projects. This is described in relation to the environment inside which it behaves. For example, in cybernetics terms a polar bear is: something (a black box) that tries (behaviour) to survive (goal) in the Arctic area (environment). Modes of cybernetic modelling, however, often stumbled on the difficulty of accounting for the duality inside the same model. This property was what the structuralists attempted to emphasise, that is, the simultaneous taking account of functioning and evolving. The cybernetic characterisation of a polar bear may indeed very well apply to an Eskimo also.

The integration of these two paradigms, the structuralist and the cybernetic, established the systemic paradigm in the middle of 1970's (Le Moigne 1977-1994). Hence, LMS' definition of the canonical model as a general system (GS) is: something (a structure) that is functioning and transforming toward a goal in an environment. Derived from the GS, the experience shows that a perceived phenomenon may be defined due to three poles or perspectives. First, the morphological, anatomical or analytical, is the static representation of substance and its composition. Secondly, the functional, physiological, praxiological, sometimes experimental, is the action of a system in its environment. Thirdly, the morphogenetical, genetic/teleological, transformational, dynamic, evolutionary or historical, accounts for a phenomenon's transformations in time toward some goals. Hence a phenomenon may also be defined as: to be, to do and to become. (Le Moigne 1990a, 1977-1994). Table 7 shows a juxtaposition of the discussed modelling paradigms.[16]

Modelling Paradigm	Essential qualities				
Rational Mechanics:	function	---	structure	closed	Determinative
Statistical Mechanics:	---	transformation	structure	closed	Determinative
Structuralism:	function	transformation	structure	closed	Determinative
Cybernetics:	behaviour		---	open	Teleological
Systemics:	function	transformation	structure	open	Teleological

Table 7. *Shows a juxtaposition of the five fundamental modelling paradigms and its essential qualities. These are the result of scientific inquiry of the Occidental civilisation. Systemic modelling, which is Le Moigne's position, represents the richest model.*

4.2.3. Systemography, Genotype and Phenotype

LMS stresses that General System Theory is a theory of modelling rather than a general theory of models (Le Moigne 1977-1994); this is in accordance to the constructivist foundation. LMS' tool for modelling then, is called Systemography (SGR). It may be recognised in analogy to photography or biography. ”Systemography is a procedure with which one constructs models of phenomena perceived as complex, representing it deliberately as and through a general system." (Le Moigne 1977-1994:28). The mode of usage of this cognitive instrument is the following: an observer, e.g. the representation system, constructs at the same time an isomorphy[17] of the GS and a homomorphy[18] of the phenomenon to be represented. Verification of the isomorphical relation will not be problematic because of the GS definition given above. The homomorphical models, on the other hand, will not produce any perfect relational model as conceived in positivism. Similar to photography, it is possible to make many systemographies of a phenomenon. The result of systemography may only be validated due to their projective feasibility. Further, the role of a modeller should be explicated, especially her/his project. When modelling of the perceived or conceived entity is exercised then the modeller should systemograph itself or become systemographed at the same time, this in order to make the systemographed entity more intelligible. Finally, in accordance with the triangular definition of GS: functional, organic and historic, systemography may be used in three modes: conception or design, analysis and simulation. (Le Moigne 1977-1994, 1990a).[19]

LMS makes use of J.P. Dupuy's (1986) conception of genotype and phenotype.[20] These manifest the usage of systemography. The genotype or the canonic model of GS that is an artificial construction of human mind, together with the modeller establishes one or many potential phenotypes of the phenomenon perceived or conceived as complex. The genotype is both a matrix and a rule: "Matrix is a model in general or paradigm /.../: a model of an organisation or of complex teleological actions; a rule (or syntagm), a procedure of construction, by homomorphism of models which are phenotypes of the phenomenon considered by the model builder." (Le Moigne 1993:13)

4.2.4. The General Process

"The representation of a phenomenon, perceived as complex by a system, rests on an explicit hypothesis of irreversible rationality, teleological and recursive." (Le Moigne 1990a) As earlier discussed SM models active systems where the inquiry focuses on the action of a system, both synchronic and diachronic, rather than on its state. Such an action is represented by a symbolic processor. This notion may be expressed well through the canonic model of a general process (GP), processed by one or many processors. "A process is defined by its exercise and its result /.../. A process exists when there is a change in position of space-form reference in time, of a collection of some products, identifiable by their morphology - their form."[21] (Le Moigne 1990a:46). Hence, the genotype of a process represents a conjunction of temporal transfer or in other words a function of time, space and form. Further, all systems may be represented as multiple actions or entanglement of processes - this is in accordance with the general system that is conceived as a composition of multiple processors.

4.2.5. Information Processing System

In order to make the reason for LMS' use of Information Processing System paradigm more intelligible, a brief return to the notion of a complex system is necessary.

A complex system must by definition be a system that manifests a certain degree of autonomy. This is because if a system's behaviour was to be completely dependent on exogenous interventions, over which it would not have any influence, it would then not be a complex system. On the contrary, it would be a completely predictable system, a programmable automaton, whose programme would completely define its predictable behaviour. In contrast, complexity appears and develops completely with the emergence of the capacity of autonomy inside a system. Hence, behaviours are elaborated by the system itself in an endogenous manner. A complex autonomous system is necessarily open to its environment. This both incites and constrains it, hence the system and its environment are transacting. The system is then both autonomous and open, therefore partially dependent - a paradox for the positivist notion. This is possible when a system has its own projects for the guidance of its behaviour, which in turn requires intelligence. Intelligence of a complex system is then defined as: a system's "/.../ capacity to elaborate and conceive its own behaviours in an endogenous or internal fashion." (Le Moigne 1990a:81). The behaviours of a complex system are adaptive, which implies intentional responses to what the system perceives as solicitations of the environment. Consequently, this invention capacity of self-finalised action takes into account the complexity of a system, because it makes intelligible - not necessarily explicable - the emergence or appearance of an adaptive, non-pre-programmed behaviour. This description may be summarised in the following hypothesis: a complex system is an autonomous system, which is an intelligent system and therefore an adaptive system. (Le Moigne 1990a)

SM uses the Information Processing System (IPS), conceived by Newell and Simon (1972), as a modelling procedure of complex systems. Such a modelling approach is required to give account of a complex system's capacity to elaborate its own projects and actions, at the same time. This capacity aims to adapt the system's behaviour to its goals, therefore the system's organisation of its goals. Hence, SM makes use of IPS' potential to represent the behaviour of such an organisation by symbolic manipulation. The canonic model of the IPS represents a conjunction of three fundamental functions: a communication system, a computation system and a memorisation system.[22] (Newell & Simon 1972, Le Moigne 1990a) "This canonic form of IPS constitutes a theory, or a plausible general model, of organisation of a complex system, capable of self-organisation /.../", therefore: "The method of representation of a complex system through the system of processing of information symbols, which is presumed to account intelligibly for its behaviours, proves easy to implement in a number of exercises of practical modelling." (Le Moigne 1990a:82-83).

4.2.6. Teleological Complexification of Functional Levels

"Nothing is less simple than the interrelation between two processors!" (Le Moigne 1990a:52). According to LMS, an active entity becomes a system when two or more processors, which constitute the system, may be distinguished by its observer. Further Le Moigne (1990a) shows that a system consisting of two processors is capable of establishing as much as sixteen endogenous interrelations, including the feedback relations. This implies potentially sixteen different behaviours of the system.[23] The inter-relation of N processors or network of processors will rapidly complexify the modeller's perception. Such complexification makes often new behaviour emerge, which is rarely predictable through linear computing, hence counter-intuitive. This challenge of the observer's cognitive limitations asks for help. SM employs an instrument that has the intention to make such situations intelligible, yet not necessarily to explain them. It builds on Simon's (1969) hypothesis of a projective functional complexification. This cognitive instrument is labelled here: Teleological Complexification of Functional Levels (TCFL). TCFL in turn builds on two basic hypotheses: the teleological hypothesis and the hypothesis of sub-systems. Operationally, it implies that when a high number of processors comprise a system of interest, which is a common situation in complex systems, human cognitive limitation is then challenged easily. Experience has shown however, that such a variety also leads to certain regularities. It is therefore often possible to observe enough dense subsystems, regularities or patterns. This quality of a complex system makes it quasi-articulable. This implies that it is possible to articulate a system's subsystems and their interrelations in reference to goal(s). This shows that while the amount and complexity of endogenous interrelations in a subsystem is great, the reverse may be said of its exogenous interrelations, which are therefore intelligible. (Le Moigne 1990a). When referring to the projects, it is then possible to deliberately arrange the functional levels into a system of processors and therefore of symbols:[24] ”/…/ as a composer deliberately seeks to compose a musical system with the aid of symbolic representation. In other words, modelling complex systems will be organised in a series of iterations between projects and symbolic representations which a modeller constructs of them.”[25] (Le Moigne 1990a:54).

4.2.7. Decision-Information-Operation System model

Following the argument of TCFL, LMS has presented a general and a priori identification of pertinent levels of complexification, in order to organise a model of a complex system. This notion is an instrument to be used by a modeller when approaching a complex system with the need of articulation of its subsystems and their interrelations, in order to make the complex phenomenon intelligible. However, LMS emphasises that such identification is much more difficult than, for example, the establishment of the General System genotype. The functional model is called: Decision-Information-Operation-System (DIOS). The identification of this model has not only been due to the TFCL-tool but also to the work of K. Boulding's (1956) nine level system,[26] the GS genotype, Simon's model of decision making and PCE's basic hypotheses (Le Moigne 1990). The elaboration process of DIOS is presented in Le Moigne (1977-1994, 1990a). Here however, only the results will be briefly sketched. LMS presents two modes of DIOS. The first and more general one is due to a six level articulation, resulting in three subsystems. While the second mode is more elaborated, due to a nine level articulation, it results in five subsystems.

The first mode is comprised of: the Decision System (DS), the Information-Memorisation System (IS) and the Operation System (OS). In this case, the DS makes decisions for the whole system, the IS memorises information and acts as a coupling or communication between the DS and the OS, while the OS does the work in the system. This may be compered with the traditional cybernetic system, the Decision-Operation-System (DOS) model, which is comprised of two subsystems, the DS and the OS. Indeed, one of the main arguments of LMS is that of the better adequacy of the systemic model compared to the cybernetic one. The systemic model, the DIOS, is supposed to perfectly reflect the phenomenological hypothesis: ‘we know only the representations of the interactions…’. At the same time, accordingly to LMS, the cybernetic model (the DOS) reduces complex systems to automata, which manifest a complicated yet predictable behaviour. This is due to the cybernetic command-control relation that imposes the will of the DS on the OS. The OS acts in perfect accordance with the commands, not manifesting any divergence. In the systemic conception such a relation between DS and OS is of a complex nature, hence expressed in the memorisation system. Further, the cybernetic system lacks memory, this reduces complexity to a simple thermostat, while the memory of the DIOS expresses the potentiality of a system and accounts for the temporal quality, hence its diachronicity. This is considered to be necessary for a complex system in order to be able to handle or manage the environment's unpredictable variation and complexity (Le Moigne 1990a).

The second mode, a little more elaborate, expresses all nine levels of Boulding's proposition. Starting from the first mode of DIOS, its DS is recursively comprised of three subsystems. These are in accordance with Simon's model of decision making.[27] The DS consists of the Coordination System (CS), which co-ordinates the numerous actions exercised in the operating system. Next is the Imagination System (IMS) that designs new forms of actions. Finally, the Self-finalisation System (FS) manifests the teleological quality of a complex system. It establishes the gap between the perceived and projected situation. Hence, the second mode of DIOS comprises the operation system, the information-memorisation system, the co-ordination system, the imagination system and the self-finalisation System (Le Moigne 1990b).

Although Le Moigne never states so, DIOS' second mode may be very well juxtaposed with Stafford Beer's (1979, 1981) Viable System Model (VSM). VSM is founded on the traditional cybernetic model, the DOS, together with neurobiological studies of human beings. In its elaborated form VSM comprises five subsystems, as the DIOS does. These are the operating system, the co-ordination system, the control system, the intelligence system and the policy system. For an overview of this discussion see table 8.

PARADIGM:	CYBERNETIC	SYSTEMIC
1st mode:	Decision, Operation: System (DOS)	Decision, Information, Operation: System (DIOS)
2nd mode:	Policy, Intelligence, Control, Co-ordination, Operation (according to Viable System Model)	Finalisation, Imagination, Co-ordination, Memorisation, Operation

Table 8. *Shows a juxtaposition of the cybernetic and systemic approaches to an a priori model of a complex system. In the cybernetic notion, mode one represents a direct relation between the observed and the observing system, while in the systemic notion such a relation is complex, hence represented by an intermediate memorisation system. The latter manifest the phenomenological hypothesis as presented before in the* ***what*** *is knowledge discussion (we know only representations of interactions between the mind and the phenomenon). Mode two presents the two paradigm's articulation of the observing system. In the cybernetic position, it is due to S. Beer's Viable System Model, as generated by biological studies of the neural system. While in the systemic position, the articulation is due to H.A. Simon's psychological studies of human decision making process.*

4.2.8. The paradigm of organisation

The implication of the previous discussions is, that in order to conceive or perceive a complex system, it is necessary to postulate some strong basic hypothesis. This is recognised by PCE. For example, in designing or identifying a complex system, it is necessary to explain projects through which it is known. The expression of a complex system embodies: the modelled experience, the modeller that is experiencing and the model that represents these two. This inseparability implies an action of organisation of representations, which results in an organisation. SM's notions of organisation is a conjunction of the action and the result, which passes through a central concept of active organisation. In the quest for active organisation, LMS has inherited and modified Morin's (1977) concept of organis-action. Hence, organis-action is: "/…/ a property of a complex system, allowing at the same time to account for behaviour of each projective level, which we attribute to the system, and of the expression between these levels, without separating them." (Le Moigne 1990a:74). Le Moigne modified Morin's formula of the active organisation by adding to it the recursive property (Le Moigne 1985a). Hence, the postulated paradigm of organisation is: Eco-Auto-Re-Organisation (EARO). It manifests the observer's cognitive action when perceiving and conceiving phenomena, as expressed in the basic hypotheses of PCE. Figure 2 illustrates EARO paradigm briefly.

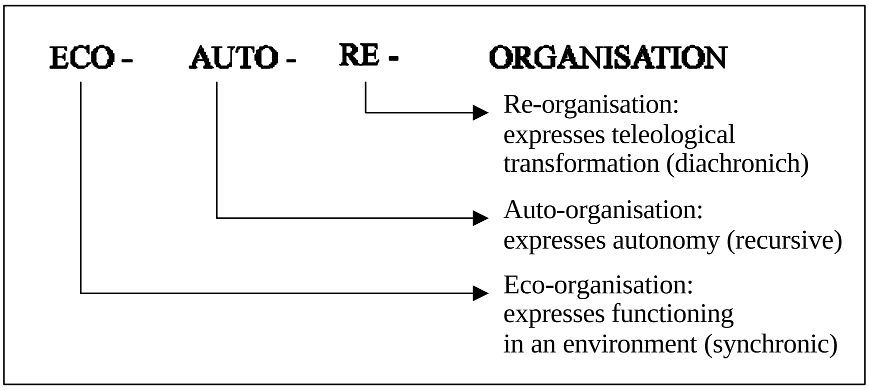

Figure 2. *Shows the fundament of systemic conception of the Eco-Auto-Re-Organisation paradigm. This is the foundation for the notion of an active organisation (or organis-action). The reader may note the relation between this model and the three properties of cognition, that is to say:* ***eco-*** *is* ***synchronic****,* ***auto-*** *is* ***autonomous****, and* ***re-*** *is* ***diachronic****. Hence, the concept of an active organisation manifest the capability of a cognitive system, that is, of an observing system that organises its perceptions and conceptions which results is an active organisation.*

Founded in EARO-paradigm, LMS proposes a canonic model of an active organisation, i.e. organis-action (see Figure 3). This aims and permits to support the representation of a complex of actions, which needs to be taken into account when modelling complex systems (Le Moigne 1990a). The active organisation genotype describes the property of a general system, that is capable at the same time of the conflictful (Le Moigne 1986b) conjunction of three recursive functions. These functions include: maintaining and self-maintaining (time-action), linking and self-linking (space action), and producing and self-producing (form-action).[28] The active organisation is thus a conjunction of itself and its environment. This means that it is, at the same time, inseparable and dependent on its environment. It is capable of differentiating from its environment due to the autonomy of a modeller's perception. Such a conjunction could not be possible without a foundation in conjunctive logic. The conjunction of the actor and his action has been expressed by Morin as follows: "To conceive the principle of complexity, it is not sufficient to associate the antagonistic ideas in a concurrent and complementary way. The very character of the association also has to be considered: Organisation that transforms each of the terms in the process of looping." (Morin 1977:381)

LMS' concept of an active organisation may be contrasted with AM's concept of organisation. The latter notion implies a passive and invariable structure of states, perfectly founded in the disjunctive logic. On the other hand, an active organisation's conjunction of actions expresses the duality of action and result, as founded in conjunctive logic. Active organisation is organised and organising in irreversible gestalts, stable enough to be distinguished by the knower that perceives or conceives it. (Le Moigne 1990a) See table 6 for a juxtaposition of the two notions of organisation.

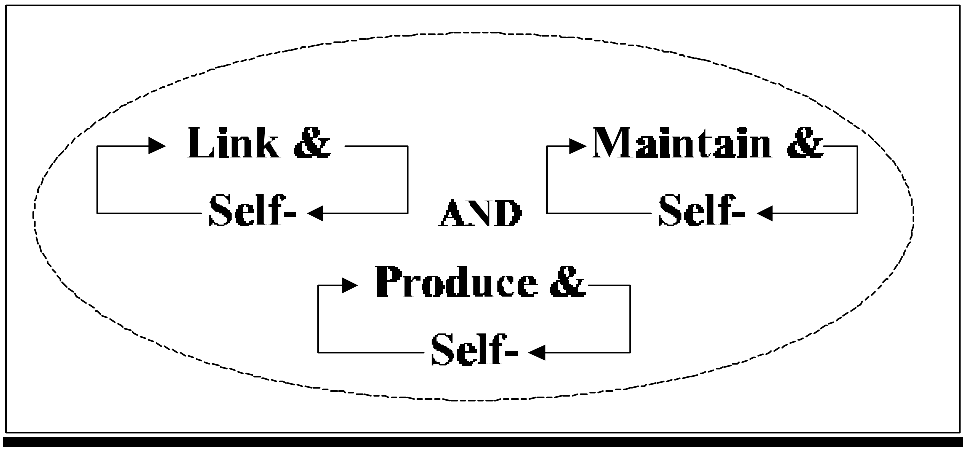

Figure 3. *Shows the canonic model of an active organisation as founded in the Eco-Auto-Re-Organisation paradigm. This model is conceived as a conflictful conjunction of three recursive functions: link and self-link (space or communication function), maintain and self-maintain (time or memory function), produce and self-produce (form or computation function).*

4.3. The Inforgetic paradigm

Due to the energetic model, the classical conception of organisation implies an arrangement of a network of stable organs, which optimise a global process of conversion of materials into energies (Le Moigne 1990a). The domination of positivism in science made physicalism and energetics the measure of all scientific knowledge. The postulate was that a good scientific discipline ought to have the reference model of mathematical physics. The energetic paradigm studies all processes of change of matter into energy and energy into matter, a process which is first identified then quantified. The inadequacy of the postulated extension of this notion to the science of mind and the social sciences became untenable, for example, when considering measuring a quantity of information with the help of a unit, a bit, which does not equate to any dimension (Le Moigne 1991a, 1997). (The argument of information will be developed more in the section that discusses information and self-organisation below). Hence, LMS associates itself with Bateson's critique of borrowing insufficiently ensured concepts as well as borrowing the supporting epistemological references, when the field of study is changed. "To consider social organizations as energetic phenomena and to interpret them in terms of energetic theory is pure nonsense." (Bateson 1972:198). Social organisations, like businesses and families, ought not to be considered first of all as processes of interaction between matter and energy, as the energetic paradigm suggested. Rather they should be considered as processes of conceptual interaction between information and organisation mediated by the decision of an intelligence. (Le Moigne 1990a)

LMS proposes an alternative paradigm to energetics, namely the inforgetic paradigm. The latter perfectly reflects the constructivist foundations. Inforgetics redefines the theoretical framework and accommodates models of complex systems, in a way that do not reduce, or destroy the intelligibility of these. The neologism of inforgetics may be considered parallel to energetics. Inforgetics focuses on the relation between information and organisation, rather than on matter and energy.

The following will present the canonic model of information and its symbol, the first and second principle of inforgetics. These are the manifestation of the inforgetic theory.[29]

4.3.1. Information and its symbol

LMS associates itself with Bateson's (1972) definition of information: 'a difference which creates a difference'. In the shadow of PCE, this may be re-written: "/…/ a representation which transforms a representation /…/" (Le Moigne 1990a:106). The operationalisation of this notion leads to the consideration of two basic concepts, necessary for all modelling. These are: information and its symbol; the latter is a physical support of the previous. The key issue concerns the relations between these two concepts, or as Le Moigne (1990a:101) puts it: "The development of complex systems modelling has long been comprised by the difficulty of establishing a stable, non-reducing definition of joint concepts of information and symbols." Analytical modelling understands information in terms of data, passive objects, pre-given to the modeller, well shadowed by the positivist tradition. "Each element of information had one and only one attached significance, presumed established without ambiguity, one expressing passive states, other disjoints expressing operations." (Le Moigne 1990a:101).

Due to the developments in semiology (C. Morris), communication theory (C. Shannon & W. Weaver), theory of organisation (H. Quaster, H. von Foerster, H. Atlan, E. Morin), anthropology (G. Bateson), cognition (J. Piaget, H. Simon), the inforgetic paradigm disposes of a canonic model of information and its symbol. This model accounts for the complexity of their relation and human perceptions, which AM's notion destroyed. (Le Moigne 1990a)

Information is considered as a composition of forms (gestalt), or stable configuration of symbols, which carry significance for its receiver with the intention to act and which have been signified by deliberative formation. This may be expressed by the conjunction of a sign (physical), capable of being at the same time, signified (designation) and signifying (production of signified sense through symbols); hence the inseparable conjunction: S^3. The symbol is at the same time physical support that is a recursive operator, assuring the function of designation and production of symbols. The conceptualisation of a reflexive operator allows the equivalence of value between operator and the operand (a symbol may be signified as an operator and as an operand at the same time). This in turn allows expression of complex phenomena perceived as recursive without reduction and destruction - something that analytical modelling could not offer because of its supporting logic of excluded thirds.

4.3.2. The first principle of Inforgetics: the Principle of Self-organising

This principle presents a generative mechanism of how an organisation organises itself - hence a theory of self-organisation (Le Moigne 1990a, 1992). LMS starts this exploration by emphasising the importance and by an examination of C. Shannon's (Shannon C.E. & Weaver W. 1949) 'Mathematical theory of communication'. Shannon emphasised that the theory focused exclusively on the signal or symbol, ignoring the semantic and pragmatic quality of information. W. Weaver in his introduction to that text, noted that information processing should not be reduced entirely to technical signal processing. As Le Moigne (1990a) notes, a contradiction occurred when an insignificant sign or symbol is postulated while the significance of a sign's probability was under consideration. Identification of information separated from its context is not possible. It is only identifiable in the context of its communication between the system of emission and the system of reception; both are inseparable from the communication system. (Le Moigne 1990a) When the epistemological spectacles are changed, the pertinence of this model for mind and social sciences emerges, however. Because it contributes to the intelligibility of a complex organisation, by being: "/…/ a starting point for formulation and useful interpretation of all different models of organising and autonomising information." (Le Moigne 1990a:110) The key aspect of Shannon's model for the theory of self-organisation is that the channel contains noise. This implies a transformation of the coded and transmitted signal; hence the medium affects the message. This model manifests the interdependency between the coding and the noise. (Le Moigne 1990a).

Next, LMS takes account of H. Quaster's (1964) model of transmission transformation. Quaster's consideration of Shannon's model resulted in a formal model making the transformation process of the transmitted signal intelligible. Briefly, this model postulates that not all information emitted by the emitter is received by the receiver, while the receiver receives some information that was never emitted by the emitter. Consequently, the channel as such, transforms the transmitted message due to the channel noise. Le Moigne (1990a) concludes: "Even if the conditions of interpretation of Quaster's model require great caution in their interpretation, can one not say that it accounts for the most common experience in communication between two systems, when one considers information in its complexity: everyone knows that the other does not hear all that was said to him and that he hears things that were not said to him. Because everyone knows it, why then ignore it! Quaster's model gives formal intelligibility to this hypothesis /…/." (Le Moigne 1990a:112)

The important quality of Quaster's model, which interpreted Shannon's, makes LMS ask the following question: "How can one account for this process of loss and gain of information in transmission, in the frequent case, when the emitting and transmitting system are one and the same? /…/ or when the control system is also the controlled system." (Le Moigne 1990a:112). LMS notes that J. von Neumann and R.W. Ashby started to tackle this issue in the fifties. In the case of multiple finished state automation systems, von Neumann (1966) underlined however that these applied to complicated systems only, not to complex systems. Ashby's (1956) principle of requisite variety on the other hand, considered as a principle of self-organisation of systems, is only applicable when the number of possible states of the self-organising system is known beforehand. Hence according to Le Moigne (1990a) this is not useful for complex systems.

The question above becomes intelligible due to the works of H. von Foerster (1959), H. Atlan (1972 & 1979) and F. Varela (1979). On the apparent paradox of self-organising systems, von Foerster proposed an original formalisation: the system, while open to noise, as was discussed above, possesses the capacity of adaptation possible by the single apparent feature of functioning. This notion is expressed in the model: 'Order from noise', and takes into account the findings of C. Shannon and H. Quaster. Following this line of inquiry, Atlan re-discussed von Foerster's notion, proposing a careful new formalisation and a label that recognised this phenomenon more adequately; hence the model: 'Complexity from noise'. On the other hand, Varela's (1979) discussion of the self-referential character of a self-informational process of a system, proposed that the self-in-formation may be conceptualised as an endogenous process of self-formation. This was in order to support the hypothesis of internal action: organising information that is processed in and by the system.

Hence, these models make the simultaneous process of information destruction and production intelligible. This phenomenon may be perceived as a process of self-transmitting, coding and de-coding of messages. In such an interpretation, the complex process of emergence of new forms out of noise - not pre-programmed - in the channel between the receiver and the emitter becomes intelligible. Inforgetics accounts for the complex conception of information and organisation that make complex system's behaviour intelligible in a way that was not possible previously - in the notion of energetics and analytical modelling. Or as Le Moigne (1990a:113) puts it: "/…/ joining the sign (a new form) and the significance, led to recognition of a joint emergence of 'new' significance, in other word, to make plausible the occurrence of 'new' possible behaviour of the considered organisation. In processing information, it self-organises."

The organisation of information - that represents a complex phenomenon[30] that a knower perceives or conceives - may be represented and exercised as such by the Information Processing System.[31] (This because IPS proposes a model that organises information.) This organisation of information is expressed by the conjunction of the three functions: 1: symbolic designation, which founds symbols in projective action, 2: symbolic computation, which configures symbols and transforms them, 3: memorisation, which registers symbolic configurations for accessibility. These three functions permit the expression of the recursive character of the action of organisation, which self-organises by in-formation. This implies an intelligible procedure that considers information as an organisation - organising and organised, therefore at the same time an operator and an operand. For the knower, to organise is both an action of in-forming (computation) and the result of this action (memorisation), it leads to designated organisation by information. The second and the third function are easily visible in the complex conjunction between the interaction of information and organisation, while the designation of information is hidden under the surface. It will however become visible in the decision processes, which mediate this interaction. These decision processes are recognised in the second principle of inforgetics. (Le Moigne 1990a)

The operational implications of this theorising, which resulted in the model of complexification due to noise, suggest at least two necessary conditions for the development of the endogenic process of self-organisation, and a better potential for an autonomous system to adapt. These two conditions are: a) that the system should be open to its environment, and b) that the system should permit some internal redundancy, hence all recourses may not be permanently occupied.[32] These qualities are of critical value for a system, because: ”When noise comes, the system can attempt to reduce and decode it, then as the case may be, elaborate new behaviours, by assimilation. It self-organises in producing forms of original organisation, which it did not ‘import’ but which it self-produced (a process of autopoiesis).” (Le Moigne 1990a:116)

The first principle of inforgetics, the principle of self-organisation or equilibration, manifesting the processes where: information in-forms organised organisation, which by organising, organises the formation of information, hence in-formed, which…. (see Figure 4). This is in contrast to the first principle of energetics that considers the mutual conservation between matter and energy, which is also called the principle of entropy.

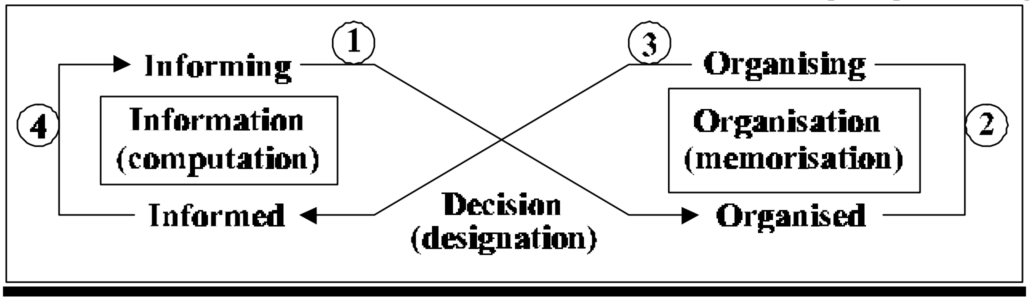

Figure 4. *Shows the principles of Inforgetic theory. Information informs (1) organised organisation, which (2) organising organises the formation of in-formation (3) thus informed, which (4)… This loop manifests relation between the two principles of Inforgetic theory (i.e. the principle of self-organisation and the principle of intelligent action) that is to say, the mental relation between information and organisation mediated by decision. The figure also shows the relation between the loop and the functions of the Information Processing System.*

4.3.3. The second principle of Inforgetics: the Principle of Intelligent Action

In order to explain the second principle of inforgetics, that is, the Principle of Intelligent Action (PIA), a brief discussion of its paralleling principle will first be presented. The latter is the second principle of energetics, that is the Principle of Least Action (PLA), (also called the principle of natural economy or maximum-from-minimum).

The second principle (of both energetics and inforgetics) concerns decision-making, in the present context. In the notion of energetics (and therefore analytical modelling), when decisions are to be taken there is an aspiration for optimum behaviour, presumed unique, for a given situation. Such an optimal decision is considered to be guided by either a unique criterion or by so-called natural laws. LMS' critique of that notion notes that there is no real choice then, because the decision is pre-determined. In the first case, predetermination is due to a unique criterion of behaviour, which mostly refers to the PLA. It is given by physicists as a natural law and imposes the axiom of doing maximum-from-minimum. The second case may be manifested by the constraints through which the environment is perceived. The system can only subject itself to eternal laws that constrain it and guide its behaviour. Therefore, to know these laws implies being able to predetermine ulterior behaviours in the system, and hence decision making of the system. (Le Moigne 1989b, 1990a, 1990b, 1995c, 1995d). AM's concept of decision making is exercised with algorithms that determine behaviours of a system. These algorithms rest on disjunctive logic axiomatics. These are also often accompanied with some factors, such as uncertainty and risk. The algorithms are often presented as those of mathematical decision theory or normative decision theory. Hence, AM's conception of decision implies an optimum command received by the system for establishing good rational behaviour. LMS' critique notes that this conception leads to a situation, that mathematicians call undecidable, where it is not possible to calculate in a certain and singular way an optimum solution to the stated problem. The paradox occurs when theories on the one hand postulate an undecidable situation, while on the other human actors are able to pragmatically decide by using deliberate reason and without the algorithms. Hence, SM accuses AM of reducing perceived complexity by ignoring the capacity of human actors, such as intelligence, conception, imagination, intention and memory. Therefore, LMS considers AM's use of energetics for decision making to be suitable sometimes for complicated, closed and predictable systems, such as programmed automata only. It is not the case for complex, open and unpredictable systems. (Le Moigne 1990a)

LMS' theory of inforgetics offers an alternative to PLA due to its Principle of Intelligent Action (PIA). Le Moigne illustrates PIA with the following Marxian metaphor:

"The bee surprises the ability of more than one architect by the perfection of its wax cells, but what makes the most mediocre architect superior to the most expert bee, is that he constructs the cell in his head before constructing it in the hive." (K. Marx, Capital, vol.1, p.174)

PIA is derived from A. Newell and H.A. Simon's work (1976) who investigate the capacity of the cognitive system to explore and construct symbolic representations of processed knowledge. PIA may be defined as the cognitive process through which the mind constructs a representation of dissonance (gap), which it perceives between its behaviours (is-situation/s) and its projects (ought-to-be situation/s), and seeking to invent some responses or plans of action, capable of restoring a wanted concordance (no-gap) - an intelligent (adaptive) action (Le Moigne 1995b). PIA focuses on dialectical models, which favour examination of previous experiences, by using heuristic reasoning for problem solving, hence founded on inductive reasoning rather than deductive, then searching feasibility or adequacy rather than objective and optimal truth. The architect in the parable is constrained like the bee by the epistemological foundation of positivist epistemologies. Changing the epistemological spectacles, the architect may offer himself other criteria than the sole minimisation of wax, such as ethics, aesthetics, weight, etc. Further and at least as important, the list he chooses is not predetermined by energetic laws, but rather created by his intellectual ability. (Le Moigne 1995b)

4.3.3.1. The canonic model of the decision process.

LMS also offers an implementation of the second principle of inforgetics, by establishing a canonic model of the decision process in complex systems. This is derived from Simon's works on problem solving.

LMS' model is founded on Simon's two hypotheses about decision making which are: a) decision is intelligence, that is teleological comprehension, and may be represented by the process of identification-formulation of problems: what are the objectives and what is the present situation; b) decision is design (conception); a cognitive process of problem solution. The conjunction of these two hypotheses allows modelling of decision processes in a general way. SM proposes two complementary implementations of decision process modelling. First, decision may be considered a stable system of symbolic manipulation, and hence represented by an exercise of symbolic computation (an IPS). Secondly, the decision process may be represented by a conjunction of three stable subsystems, which are in themselves recursive. These three subsystems are: a) a system of intelligence: problem formulation, b) a system of design: problem solution, and c) a system of selection: multi-criteria choice of decision action. This model stresses some important qualities. First, a decision process in complex systems is fundamentally teleological. Secondly, the problems are not previously given but constructed by the modeller, hence there is self-finalisation. (Le Moigne 1990a)

The essential difference between AM and SM is that AM considers the decision-making act as a result, capable of being analysed and disjoined. While SM considers decision-making as a sequential process of information processing, developed inside a complex organisation, from which it is not separable. SM considers the problem of decision-making in complex situations to be one of qualitative representation, rather than of quantification and algorithms. The main issue then is how to represent, and consequently of what-to-do; rather than of how-to-do or solve by algorithms, as AM stresses (Le Moigne 1990a). Further, in complex situations all decisions are multi-criteria decisions; that is, there exists more than one satisfactory solution to a single multi-criteria selection, but no single optimum solution. The optimum may be found in simple, (closed and well-structured) mono-criteria situations. Therefore heuristic reasoning, searching for satisfying solutions is preferred, rather than algorithmic reasoning looking for an optimal solution, which may never be found in complex, multi-criteria situations. (Le Moigne 1990a; Le Moigne & Bourgine 1990d) For an overview of the two discussed paradigms see Table 9.

PARADIGM OF NATURAL UNIVERSE:	1st Natural Universe: ENERGETICS	2nd Natural Universe: INFORGETICS
Concerns:	The process of conversion between energy and matter, and vice versa; concerns natural sciences	The conceptual interaction between information and organisation, and vice versa, mediated by decision of intelligence; concerns mind and social sciences
Notion of Information:	Passive and disjuncted data, without ambiguity	S3: deliberately Signified Sign making Signification; complex conjunction of the operator and

			the operand
1st Principle:		Principle of mutual conservation between Energy and Matter (PEM);	Principle of Self-Organisation (PSO); or principle of equilibration
2nd Principle:		Principle of Least Action (PLA); or principle of maximum-from-minimum	Principle of general Intelligent Action (PIA); or principle of teleological adaptive behaviour
some characteristics of the 2nd principle:	searches for:	a unique optimum	a satisfaction or adequacy
	focuses:	quantity, hence: How-to-do?	quality/representation, hence: What-to-do?
	uses:	algorithms	heuristics
	qualities of the domain of concern:	determinative, closed, mono-criterion, pre-determined systems;	deliberative, open, multi-criteria, unpredictable systems;

Table 9. *Shows a juxtaposition of the two natural universes of human experiences, that is to say the energetic and the inforgetic. These are founded on the two epistemological positions, the positivist and realist paradigms and the constructivist paradigm, respectively.*

5. A summing up the significance of LMS

Le Moigne's contribution will certainly need to be critically evaluated from different perspectives in order to assess its particular value. One attempt has been done by Eriksson (1997). In this section, the author will attempt to briefly sum up what he thinks is Le Moigne's significant contribution.

Le Moigne's contribution can be considered impressive in its ability to scan a very large amount of research findings from diverse domains, identify and extract the crucial ideas, and transform and relate these to each other, in a way that few would expect possible. Le Moigne is primarily occupied with the meta-modelling of theories. In this manner his contributions may be considered as follows.

5.1. Epistemological formulation

Le Moigne's formalisation of the basic assumptions of constructivist epistemologies (Le Moigne 1995b) into a coherent framework is important, especially if this domain is to be considered teachable. The crucial argument of theory validation is easily visible and it offers a reasonable alternative to the objectivist and relativist positions. This formalisation framework helps us to understand the similarities and differences between the different theories of human mental constructions, such as constructivism as a doctrine, constructivist epistemology, social construction theory, social construction of technology, etc., with several branches within each mentioned. Constructivist epistemologies establish a firm foundation for designed, artificial, engineered, organised systems - or in LMS' notion for systems science. These domains may manifest their epistemological foundations without being reduced to the so-called applied sciences. These foundations are justified just as well as those of the analytical sciences.

5.2. General Systems Theory

Le Moigne presents (1977-1994) a formalisation of a General Systems Theory (GST) and a distinction of the different modelling paradigms. He syntheses the cybernetic model with the structuralist one, resulting in the systemic model. GST has been around as a concept at least since L. von Bertalanffy. It seems though that there has been a lot of confusion about what it really implies. In von Bertalanffy's notion - without neglecting his contribution - it seems to be primarily a theory of open systems. Further, GST has been often confused with cybernetics and considered to be one and the same (for example Ericson 1972). Le Moigne makes it clear that cybernetics and GST, although overlapping, are two different theories.

Le Moigne's notion of an a priori systemic model of system levels (DIOS) comprised of the decision system, memorisation-information system and operation system informs the cybernetic notion, comprised of two systems: the decision-making and the operating systems. In cybernetic terms the operation system must obey the directives of its decision system and eventually report to the latter. The cybernetic model manifests some misconceptions when considered in relation to the systemic one. When applied to psychological and social domains, the implications of constructivist epistemologies state that this one-to-one relation (realist/positivist) may not be assumed, because mental schemes fit the experiences of the cogniser rather then match the ontic reality. Furthermore the cognitive system manifests intelligence, memory, imagination, etc. and the relation between the decision-making system and the operating system is of a complex nature, represented in the systemic model by a memorisation system.

5.3. Theory of an active organisation

Similar to GST, LMS offers a formalisation of the theory of active organisation. He has enriched Morin's notion with recursiveness and presented something that is distinct from the traditional invariant or passive notion of organisation. The active notion recognises, for example, that organisation is perception of an observer (hence necessary active), and that it manifests pluralism and power relations.

5.4. Inforgetic Theory

Inforgetics offers the modeller a foundation for the psychological and social sciences in terms other than those of the traditional positivistic approach. Hence, the notion that mind and social domains are fuzzy or less exact than the domains of the natural science, is a misconception in the light of Inforgetic theory. This is because the statement of fuzziness or of what is exact or not, is postulated in reference to the energetic foundations, the latter being presupposed. As pointed out by Bateson and Le Moigne, a change of the scientific domain should be accompanied by a mediation of the epistemological foundation of their inquiry.

The inforgetic principle of self-organisation manifests a plausible theory of how open systems self-organise. It is founded on established and rather stable research findings of Shannon and Weaver, von Foerster, Quaster, Atlan and Varela. The same may be said of the principle of intelligent action, established by Simon's life long research in decision and cognitive science. Le Moigne's conjunction of the two aspects of inforgetics into one single framework may be considered original (information in-forms organisation which in turn organises information, which…; this loop is according to Le Moigne mediated by the decision of an intelligence, with capacities of imagination, memory, etc.). Such a notion recognises human beings as intelligent - both emotional and rational. This is in contrast to attempts by chaos or fuzzy set theory that reduce intelligence to mere chance.

5.5. The grand synthesis

Le Moigne has succeeded in synthesising the very different and rich research findings into one single and coherent system of thought. The foundations of projective constructivist epistemology are clearly visible in the procedural rationality mode, the general systems theory, the Eco-Auto-Re-organisation paradigm, and the inforgetic theory, these four clearly interacting with each other. The whole framework manifests a conjunction of research exercised both in Europe and in America, at different times and in different intellectual traditions.

Acknowledgement

I would like to express my gratitude to Professor Jean-Louis Le Moigne for his help and guidance in my studies of systemics. This also applies to his student Mr. Pascal Vidal. Mrs. E. Mostovac's help with the French prose was pivotal in this work. Mrs. V. de Raadt and Dr. A. Basden's help with the English prose was essential for the present article. I would also like to thank the anonymous reviewers and the editor of this journal for valuable suggestions for modifications. Any misconception in this text however, ought to be assigned exclusively to the present author. Further, the support given by the Department of Informatics at Mid Sweden University and the Department of Informatics and Systems Science at Luleå University of Technology has been significant.

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Notes

[1] The present author's intellectual contribution is only a summary of J-L Le Moigne's original publications over the last 25 years.

[2] Stands for: "Groupe de Recherche sur l'Adaptation, la Systémique et la Complexité Économique"

[3] "The Theory of General System is a collective work, one of a generation. It is not a property of a school, nor of a nation, nor of a discipline." (Le Moigne 1977-1994:2).

[4] The original texts of LMS often make the presentation of its ideas in contrast to the positivist and the realist paradigms (Le Moigne 1991b). Such an approach will be used here in order to facilitate intelligibility.

[5] The three questions elegantly manifest the canonic model of the general system (GS) of LMS, where the what expresses the structural quality,

the how manifests the functional quality, while the why the transformational. GS will be discussed further on in this presentation. These three questions are also given by Piaget (1967).

[6] For a brief review of Le Moigne's main texts on constructivist epistemology see van Gigch (1996).

[7] PCE is fundamentally influenced by J. Piaget's works on cognition (for example: Piaget 1937, 1970). His mission was to explain knowledge in biological rather than philosophical terms. This resulted in a theory of cognition that considers the function of human knowing as adaptive in the biological sense, the goal of this adaptation is to provide viability to the cognising organism. Le Moigne does not present Piaget's theory in his own works, he rather assumes that the reader is already familiar with these and consequently builds his own reasoning on that assumption. It is beyond the scope of this text to change that assumption. Hence, the reader ought to be somewhat familiar with the key issues in Piaget's works, he may also consult von Glaserfeld's (1995) recent presentation.

[8] In this argument Le Moigne (1977-1994) uses the argumentation of Betz F. and Mitroff I. (1974).

[9] For a short and strong argumentation for a science of autonomy see Morin (1982).

[10] Transductive reasoning refers to the possibility of transducing or transferring reasoning from one domain to another, due to a certain degree of homomorphism. Retroduction refers to the reasoning ability due to feedback.

[11] In other words, the teleological precept means that the observer should ask what is/are the goal/s of the observed phenomenon and then what is the behaviour and the environment that relates to the goal/s, without worrying too much about what that phenomenon may be made of, its internal structure. When plausible theses of this kind are acquired, then the procedure of understanding may proceed with hypothesising the internal structure of the experienced phenomenon.

[12] Le Moigne (1990 & 1977-1994) presents a plausible model of complex behaviour emergence, which may be intelligible, yet not necessary explicable.

[13] Mono-criterion problems have one criterion that determines the choice of means for problem solving. Multi-criteria problems have many, most often contradicting criteria that do not allow to find one optimal solution but rather several satisfying solutions.

[14] See also Le Moigne's (1995c) recent contribution to Weaver's discussion.

[15] Sometimes referred to as: structural-functionalist.

[16] The quantum mechanic modelling paradigm is excluded from LMS' discussion.

[17] Le Moigne (1977-94:77) defines isomorphism as: "A bi-jective correspondence, such that to each element of the beginning ensemble (the model) only one element of the end ensemble (object) and reciprocally corresponds. This correspondence is transitive, reflexive and symmetrical." In other words isomorphism refers to the same forms.

[18] Le Moigne (1977-94:77) defines homomorphism as: "A sur-jective correspondence, such that to each element of a beginning ensemble corresponds at least one element of the end ensemble, without reciprocity. This correspondence is transitive and reflexive but not symmetrical." In other words, homomorphism refers to similar forms.

[19] Two examples of Le Moigne's application of Systemography are in Le Moigne (1977) and (1987).

[20] J.P. Dupuy's definition is: "By genotype, I mean a matrix, a structure, a mechanism, a rule by which to play. Thus it is not necessarily the genome of a living being... What are the phenotypes that this genotype is capable of producing or likely to engender? Today we know that even for very simple and particularly deterministic genotypes, the answer to this question may be inextricable complex: because phenotypes themselves are complex, because the whole they make up constitutes an inexhaustible wealth, because during the transition from genotype to phenotype problems of calculability arise which are difficult, if not impossible to resolve... Even when it is a mere figment of the imagination, a genotype or model is nonetheless endowed with a certain autonomy and able to produce the novel and the unexpected... The transition from genotype to phenotype would imply not the actualisation of a potential but the achievement of virtuality." (J.P. Dupuy 1986:255-256).

[21] The concept of form is due to the Gestalt theory, elaborated in the beginning of this century, in order to take account the psychology of perception. LMS then, defines gestalt as: "/.../ a perceived field, by that which is distinctive from depth, in a sufficient stable manner, from which however, it is inseparable. It emerges by structuring (formation of patterns) although its shape seems to belong to it, whether this structuring is geometric or conceptual." (Le Moigne 1990a:47).

[22] The reader may observe the correspondence between the two genotypes of GP and IPS. Both focus on the three aspects: time = memory, space = communication, form = computation.

[23] Le Moigne (1990:a) conceptualises the variety of a system in the sense of R. Ashby (1956).

[24] This argument shows the usefulness of the Information Processing System.

[25] This refers to the use of Information Processing System.

[26] Boulding's (1956) nine levels manifest increasing complexity of phenomena in science as follows: frameworks, clockworks, thermostats or cybernetic systems, open systems, genetic-societal systems, animal systems, human systems, social organisations and transcendental systems.

[27] This refers to Simon's (1960) three phases of decision making: Intelligence-Design-Choice.

[28] The reader may note the relation of these three recursive functions to the canonical models of General Process and of Information Processing System. That is: link = space, communication; produce = form, computation; maintain = time, memorisation.

29 LMS' Inforgetic paradigm offers also an Inforgetic model of an organisation, which is a conjunction of the DIOS model and the EARO paradigm. This model is not presented in the present text however, because of the limited published information that describes it.

[30] Because organisation of information by an IPS represents a complex perception or conception then it also represents a General System and a DIOS.

[31] This discussion focuses on the organisation of information and their symbols process*ed* by an IPS. While the previously given account of IPS in this text, focussed IPS as process*ing* information. Hence, the IPS' two modes have together four basic functions: to generate, to memorise, to communicate and to compute information. The last three are intertwined and recursively related to the first (Le Moigne 1990a).

[32] The reader may note that this last quality is well reflected in the DIOS model, due to its

memory system, permitting potentialisation, therefore management of environmental complexity, which is not the case with the cybernetic model.